

A propose of Rules Defining as a Didactic Transposition Should Occur or be Achieved - the Generalized Didactic Transposition Theory¹

Uma Proposta de Regras que Definam como uma DT deva Ocorrer ou ser Realizada - A Teoria da Transposição Didática Generalizada

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Abstract: We present the most current version of the theory of didactic transposition that encompasses (synthesizes) Theory of Chevallard (1991), the Cognitive Theory of Science (CTS) and Mental Models of Jhonson-Laird (1980). Is made here a brief review of Chevallard theory and exposes the generalization of this theory by author according to the work of Izquierdo-Aymerich (2003). That is, it is proposed here a theory to study how the knowledge scientific (the original scientific models) are transposed to the didactic models. That is, to analyze how the knowledge produced in the 'academic environment' change, adapt, simplify and consolidate as knowledge to be taught in the classroom. Complementing the work of Chevallard (1982), Brockington (2005) and others we re-present the characteristics that define the reason of a certain knowledge to be present in textbooks and propose rules defining as a DT should occur or be achieved.

Key Words: Didactic transposition, scientific paradigm, school scientific activity, the textbook analysis, conceptual mapping.

Resumo: Apresenta-se aqui a versão mais atual da teoria da transposição didática (DT) que engloba (sintetiza) a teoria de Chevallard (1991), a Teoria Cognitiva da Ciência (TCC) e Modelos Mentais de Jhonson-Laird (1980). Faz-se uma breve revisão da teoria de Chevallard e se expõe a generalização dessa teoria pelo Autor segundo os trabalhos de Izquierdo-Aymerich (2003). Isto é, propõe-se aqui uma teoria para se estudar a maneira como o conhecimento científico original é transposto ao conhecimento escolar, ou seja, as teorias e modelos didáticos. Isto é, uma teoria para se fazer a análise como o conhecimento produzido nas 'esferas acadêmicas' se modificam, se adaptam, se simplificam e se consolidam como saberes a serem ensinados em sala de aula. Complementando os trabalhos de Chevallard (1982), Brockington (2005) e outros reapresentamos as características que definem a razão de um

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determinado saber estar presente nos livros textos e propomos regras que definam como uma DT deva ocorrer ou ser realizada.

Palavras-chave: Transposição didática, paradigma científico, atividade científica escolar, análise do livro didático, mapas conceituais.

Introduction

Within the context of editorial policies, national programs of textbooks production and formulation of public policies it is very important to understand how scientific knowledge is transposed to textbooks and how this is actually taught in the classroom. The scientific theory that addresses this problem is called the Didactic Transposition.

We present here the current form of the theory of Didactic Transposition (DT) that is denominate Theory of Didactic Transposition of Chevallard, Izquierdo-Aymerich and author (DT-CHIM). Originally the theory of DT was conceived by Chevallard (1985) as a way to analyze how the knowledge produced in scientific spheres is translated to the school levels - high school. The Chevallard's theory of DT is focused on socio-cultural aspects of how the transformation of knowledge occurs and not in the semantics and epistemological aspect of this.

The ideas and concepts developed by Chevallard (1991) were developed to study the passage of the "knowledge" from the research environment to the high school. In this didactic transposition model it does the simplification that the research environment is unique. Namely, that the knowledge produced in the research environment is already produced in final form to be transposed directly to the high school. But the theory of DT can be applied to the structure of higher education [author, 2016a] since the transformation of scholarly knowledge begins in this sphere of knowledge (or Epistemosphere). With the spread of courses and graduate programs it was created another substrates between the knowledge produced in research spheres and the basic university education. We have now five levels of presentation or transcription of knowledge. The level: 1) Research; 2) Postgraduate; 3) Academic; 4) Basic graduation and finally 5) high school.

As previously mentioned [author, 2016a] with the expansion of the publishing market we have today a relative variety of textbooks produced within this epistemosphere. This created the possibility and the need to produce new proposals for education. Currently, we have research that point to the fact that one should take into account the design characteristics of presentation of knowledge [Schnotz, 2005]. This production generated a certain amount of textbooks with features, methodologies and specific objectives. Thus the theory of DT should cover their socio-cultural, epistemological, semantic and editorial aspect.

Thus, a current theory of DT must take into account that this occurs in cascading from the research environment to the university environment, and from this to the educational system of high school [Author, 2016a, 2016b and

2016c]. It can be shown that as knowledge is transformed, updating and adapting to a certain level of knowledge their explanatory models will be adjusting to the knowledge level of the target audience and to the current scientific paradigm [Author, 2016b and 2016c].

Author demonstrated (2016a, 2016b and 2016c) that due to scientific theories be developed through concepts, called nodes or links by Latour (1999), the conceptual mapping is the natural and most appropriate tool to perform this analysis.

The Theory of Didactic Transposition of Chevallard, Izquierdo and author (DT-CHIM)

Briefly the Didactic Transposition Theory is a theory that involves the epistemology of science, cognitive science theory, didactic education and social theories to understand, create rules and study the mechanisms governing the process of transformation of knowledge produced in the research spheres to the academic field, and from this for textbooks and from this to the classroom of high school.

Chevallard (1991, apud Alves Filho, 2000) classifies the knowledge into three categories. The academic knowledge, called for him the scholar Knowledge. The knowledge contained in textbooks, the Knowledge to be Taught. And the knowledge as taught in the classroom, or the Knowledge Taught.

It is within this context that the Chevallard theory of DT deals with the problem to understand, classify and study how the knowledge produced in the academic spheres will be adjusting, adapting and transforming into scientific knowledge taught in the classroom.

According to this theory, a concept to be transferred, transposed from one context to another, undergoes profound changes. To be taught, the whole concept keeps similarities with the idea originally present in your research context, however acquires other own meanings of the school environment in which will be inserted. This transposition process transforms knowledge, giving it a new epistemological status (Astolfi, 1995; apud Brockington, 2005).

It can be shown [Author, 2016b] what school science and scientists science have in common is that their theoretical ideas, concepts, were arrested and sealed in black boxes after gaining importance and after become more "solid" and "strong", that is, after "consolidated" - Latour thesis (1999). That such packaging process leaves out details, explanations and reasons that were necessary to convince others of their "original power to explain" - both to the scientific level and to the educational level [Izquierdo, 2003].

Author (2016c) demonstrates, for the case of the topic of physics called Photoelectric Effect, currently the scientific knowledge is structured didactically in their transcriptions to textbooks in: a) models; b) the core of the theory; c) experimental facts; d) the key concepts; e) the methodology and f) the

application of the theory. Thus, it is necessary to understand how these "pieces of knowledge" are inserted, deleted, and summarized to make each text a coherent whole.

Author (2016a, 2016c) divides the theory of DT in two parts. One part of the theory deals with the socio-cultural influences on didactic teaching [Chevallard, 1991; Brockington, 2005]. And the other is concerned with the epistemological and semantic aspects of the theories and how these are translated to the textbooks [Author, 2016a, 2016b and 2016c].

In his theory Chevallard divides the DT process in three stages. Thus, the Chevallard DT studies how the scholar knowledge becomes the Knowledge to be Taught and how this becomes the Knowledge Taught. Author (2016a, 2016b and 2016c) demonstrated that the theory of DT should consider that the knowledge produced in research spheres (scholar knowledge) is consolidated and/or regulated in the post-graduate programs (sphere), the academic knowledge, then transposed to the level of the Bachelor and finally transcribed or adapted to the level of the high school (the Knowledge to be Taught). This is necessary because we have today textbooks designed for post-graduate courses and graduation. Strictly speaking we would have to subdivide the graduation degree in academic and university basic level cycle. See Author (2016a). So we have to divide the Scholar Knowledge into three parts. Scholar Knowledge (Research Level), the Academic Knowledge (Post-graduation Level) and the University Knowledge (graduate level).

Scholar Knowledge → Academic Knowledge → University Knowledge →
Knowledge to be Taught → Knowledge Taught

After Chevallard to deeply understand how scientific knowledge is transcribed to textbooks we have to include in their analysis the external environment in which it occurs. This transformation occurs within an environment or within a university sphere (the Didactic System) that is within a small universe that is the external environment (the education system). In addition to these environments we have the school environment where effectively occurs the DT. That is, we have to take into account that there are factors outside the school system, embedded in a wider environment where all these spheres coexist and influence [Brockington, 2005].

Chevallard (1991) uses the word noosphere to designate and encompass the elements involved and regulating the selection and determination of the changes that scientific knowledge will suffer to become school knowledge. The noosphere is composed of scientists, educators, teachers, politicians, authors of textbooks, among others [Brockington, 2005]. Due to the diversity and richness of existing factors in the academic sphere governing the selection and standardization of scientific knowledge Author called this environment epistemosphere.

Within this epistemosphere we have, in the case of exact courses, books of Physics written for courses based on calculus and the other based on algebra. We have Conceptual Physics books, Physics for Engineers and traditional. Author (2016b and 2016c) demonstrated that DT for the basic cycle occurs from these texts and not from the original articles. Thus a theory of DT should study and track how the knowledge or scholar Knowledge is transformed in this epistemosphere to get to Knowledge to be Taught.

After this phase, the knowledge is transformed within the context of editorial policies, national programs of textbooks production and formulation of public policies to achieve the textbooks and be effectively taught in the classroom. This is where the teaching methodologies and pedagogical proposals come into play. That is, when studying or analyzing the transformations that knowledge suffers to reach the school environment we should consider both the epistemological aspects of science as their pedagogical and methodological aspects of teaching.

Like every theory of human and social sciences, the DT theory does not contain "closed" Laws or rules defining as a DT should occur or be achieved. But even so, Chevallard proposed some characteristics that define the reason that a certain knowledge to be present in textbooks. Chevallard (1991) defines some of these characteristics. In summary these are (Brockington, 2005):

- 1 - Consensual: The Noosphere members must agree that a given knowledge is definitely established. That is, it is not speculative or that there is no doubt in the scientific community.
- 2 - Moral Actuality: The Noosphere members must agree that a given knowledge is relevant and necessary in order to be entered or remain in the school curriculum.
- 3 - Biological Actuality: The content taught should be consistent with the theories or current models or accepted by the scientific community. While this is seemingly obvious, there are pedagogical exceptions. For example, we have the fact that Thomson models, Rutherford and Bohr are still being taught in schools.
- 4 - Operability: For a Knowledge be implemented and remain in school curriculums this should generate questions, exercises and problems. As an example we have all the textbooks discuss in detail the theory of the photoelectric effect and on the other hand few address in detail the theory of blackbody radiation.
- 5 - Teaching Creativity: Chevallard has coined this term to be able to explain the reason to teach subjects of science that are currently not part of the research field.
- 6 - Therapeutic: One of the reasons a particular knowledge to stay in school curricula is to your success in the classroom.

Due to the great scientific and technological advances, and needs of the school curriculum updating, Chevallard and Johsua (1982; cited in Astolfi, 1995)

has produced five rules for DT (Alves-Filho, 2005). We will list below only their first two, which from our point of view fit within this classification, that is:

7 - Modernizing school knowledge. The curriculum should address current subjects, such as: a) superconductivity; b) nanotechnology; etc.

8 - Update the knowledge to teach. The noosphere agents must define what knowledge should be removed from textbooks because they are obsolete.

From our point of view the fourth Astolfi rule (1995) is included in the guideline 4 (Operationality) of Chevallard. And the rules 3 and 5 fall into guidelines or suggestions for how the DT should be made.

Didactic Transposition and the Cognitive Model of Science

Recent contributions from epistemology of science for science teaching led to a new approach (theory) of the latter called "cognitive model of science" (CTS) that originates from Kuhn's philosophy of science [Izquierdo, 2003]. Along with the theory of "didactic transposition" suggest the possibility to analyze with more depth as knowledge produced in scientific spheres are translated to the school sphere.

Author (2015b and 2015c) demonstrated that to understand how the knowledge produced in research spheres (scholar knowledge) is transposed to the school spheres should take into account what is actually meant by scientific knowledge and to do science.

According to Izquierdo-Aymerich (2003)² when we simplify or define, with didactic purposes, what is science or to do science we can describe it as a way of thinking and acting in order to interpret certain phenomena and to intervene through a series of theoretical and practical structured knowledge. As a result of science education is desirable that students understand that the natural world has certain characteristics that can be modeled theoretically. Because of this we present to them, making a DT, some reconstructed facts, theoretical models, arguments and propositions that were previously selected.

In addition, if the teaching of sciences is done in accordance with the principles of meaningful learning (Ausubel, 1977), that is, a well executed didactic transposition (Chevallard, 1990), the teachers will be involved in the task of connect scientific models to used by pupils themselves, using analogies and metaphors that may help them to move from the last for the first (Duit, 1991; Flick, 1991; Ingham, 1991; Clement, 1993).

So to teach science we have to teach systems or methods of acquiring knowledge and at the same time, teach how to arrive to this organized body of knowledge from them. But in general it is impossible to reproduce in the classroom [Izqueirdo, 1999]. Thus, the question arises: What is to teach science in high school classroom as in the university?

If we analyze the textbooks written for high school, from the point of view of knowledge and its method of obtaining, we see that these are classified into

² The following two paragraphs are a collection of statements that together form the definition of that is the DT from the CTS point of view.

two types: a) those who start exposing the theory and then presenting the experimental facts that leads to its formulation or discovery as a mere confirmation of its validity or importance. b) and those that begin exposing the experimental facts that resulted in its formulation and putting the theory as a direct consequence of these facts. With the introduction of modern methods of teaching we have some alternative versions of exposure of textbooks. For example, we have textbooks written in the problem-based learning (Glencoe, 2005) in which each topic is preceded and motivated by the presentation of a puzzle that contextualizes the need of the search or theory formulation.

Like every theory of human and social sciences, DT theory does not contain "closed" Laws or rules defining as a DT should occur or be achieved. Within the current context of science education in the basic cycle and university we can suggest some guidelines for how the DT should be made.

1 – Partition of knowledge: Divide into its constituent parts, that is, between theory, model, experimental facts, applications, historical facts, etc.

2 – Articulate the "new" knowledge with the "old" (Chevallard, 1982; cited in Astolfi, 1995): When teaching a new theory, such as special relativity, the author and/or teacher should make clear that the old theory (in this case the classical mechanics) is still valid within their limits of validity (at low speeds).

3 - Make a concept understandable (Chevallard, 1982; cited in Astolfi, 1995): We must rewrite or redraft a concept to the level of students understanding.

4 - Making a model significant: To adapt and/or modify the theoretical models, or the scientific models to the level of students understanding. Or connect it to the model used by them.

5 - Simple Math: Scientific knowledge should be redrafted using an appropriate mathematical formalism to every school level.

6 - Pedagogical Actuality: Scientific knowledge must be redrafted in accordance with a teaching methodology. For example, according to the methodology of problem-based learning.

7 - Functional Actuality: Scientific knowledge should be drawn up according to the type of training required for each course. For example, text to train engineers.

To justify the introduction of 6 and 7 guidelines we currently have several university courses with various educational proposals. Some proposes to train scientists in general and others to train professionals for the labor market. A line of educators argue that science education should somehow reflect what is scientific activity and do science. But others argue that science should be taught in an objective manner. That is, it should be taught the concepts, theories and applications without worrying about doing science. Thus, the science teaching at school cannot be strictly based on the analogy of the student as a future scientist, that is, with a strong scientific basis [Izquierdo-Aymerich, 2003].

In the first line Izquierdo-Aymerich and Aduriz Bravo (2003) distinguishes between the characteristics of two sciences, the science of scientists and what they call school science. They argue that both sciences have a common

cognitive goal: understand the world and communicate theoretical ideas accurately and significantly. Moreover, they propose that the didactic transposition process is to recreate the science of scientists in the classroom, according to their own institutional values, rhetorical tools and educational goals, to convert it into school science.

Mental Models

To justify the introduction of the guideline 4 we have the fact that many authors [Johnson-Laird, 1995 and 1987; Nersessian, 1992; Moreira 2002] defend the idea that the students to think about a scientific fact do not use scientific models, but mental models. This cognitive fact originates a research field called previous or alternative conceptions [Gilbert and Swift, 1985]. Thus, for a given knowledge be transposed pedagogically, that is, according to the most current knowledge of science education, this should take into consideration how scientific models must be connected to the students models, ensuring meaningful learning [Ausubel, 1977].

But what would be these models used by the students? Without going into details in the various forms or types of reasoning, we have that Johnson-Laird (1983: 163) argues that people reason through mental models. Mental models, the analogically to the architecture models, are as cognitive building blocks that can be combined and recombined as required. Like any other models they represent accurately or not the object or situation itself. One of its most important features is that its structure is similar (analog) to this situation or object [Hampson and Morris, 1996, p. 243].

Analog models are often used to do research, create, test, and communicate ideas (Bent, 1984). The analogy is an effective way to explain new ideas since the explainer and the listener understand the analogy in the same way. The analogy is familiar object call, experience or process [Moreira, 2002]. Analog explanations work when the explainer and the listener agree with analog mappings that exist between the analog (prior knowledge) and the target (scientific knowledge) and mappings are said to be shared when both parties agree that the analog is similar to target in this or that way.

In other words, mental model is an internal representation of information that corresponds analogously to the state of things that is being represented, whatever it. Mental models are structural analogues of the world [Moreira, 1996].

As an example we have the atomic model. Depending on the level of education when we ask what would be the atomic model we would have a different answer. The model of Thompson, the Bohr or Quantum Mechanics. Thus, there is not a single mental model for a given state of things. On the other way, there may be several models, even if only one of them represents accurately this state of things. Each mental model is an analog representation of this state of things and, conversely, each analog representation corresponds to a mental model [Moreira, 1996].

But there is a basic difference between conceptual and mental models (Gentner, 1983 apud Norman p. 8). Physical models are conceptual models, that is, models built by researchers in order to develop his theories and contribute to the understanding and teaching of physical systems. It is an accurate, consistent and complete representations of physical phenomena according to a certain theory [Moreira, 2002]. However, the models of the students, or any individual, including those who create conceptual models are mental models, that is, models that people construct to represent states of physical things (as well as states of abstract things) through their common experiences. [Johnson-Laird, 1983; Moreira, 1996; Greca 2002].

Results and Discussion

We presented above an attempt to create rules and standards to study and classify as a DT occur and how would be the ideal DT. Like any field of scientific knowledge, especially human, this is very dynamic and challenging. So that these rules should be considered within its scientific and pedagogical actuality. They are based on years of work by researchers as Chevallard, Izquierdo-Aymerich, Pietrocolla, Johnson-Laird, Moreira, Nersessian and others. Although Author have achieved prove some of the ideas proposed here through the analysis of textbooks using as tool conceptual mapping, may occur the need to include, replace or reformulate some of these ideas.

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References

- Alves-Filho, J.P. (2000) - Atividades Experimentais: Do Método à Prática Construtivista. *Tese de Doutorado*, UFSC, Florianópolis.
- Astolfi, J-P & Develay, M. (1995) - *A Didática das Ciências*. Papirus. Campinas.
- Ausubel, D. (1977) - The facilitation of meaningful verbal learning in the classroom. *Educational Psychologist*. Volume 12, Issue 2.
- Ausubel, D. (2003) - Aquisição e retenção de conhecimentos: uma perspectiva cognitiva (1ªed.) Lisboa: *Plátano Editora*. (Written in Portuguese)
- Bent, H. (1984). Uses (and abuses) of models in teaching chemistry. *Journal of Chemical Education*, 61, 774–777.
- Brockington, G. e M. Pietrocola, M. (2005) - Serão As Regras Da Transposição Didática Aplicáveis Aos Conceitos De Física Moderna? *Investigações em Ensino de Ciências* – V10(3), pp. 387-404. (Written in Portuguese)

- Chevallard Y. La Transposición Didáctica: del saber sabio al saber enseñado. *La Pensée Sauvage*, Argentina.
- Chevallard, Y. & Johsua, M-A. (1991) - Un exemple d'analyse de la transposition didactique – La notion de distance. *Recherches en Didactique des mathématiques*. 3.2, 157-239,1982.
- Clement J. (1993). Using Bridging Analogies and Anchoring Intuitions to Deal with Students». Preconceptions in Physics. *Journal of Research in Science Teaching*, 30(10), pp. 1041- 1057.
- DUIT, R. (1991).On the role of analogies and metaphors in learning science. *Science Education*, 75(6), pp. 649-672.
- Flick L. (1991). 'Where Concepts Meet Percepts: Stimulating Analogical Thought in Children', *Science Education* **75**(2), 215–230.
- Gentner, D., and D. Gentner. (1983). "Flowing waters or teeming crowds: Mental models of electricity (pp. 99-129)." *Mental models*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Gentner, Holyoak, Kokinov; (2001). The Analogical Mind. *Perspectives from Cognitive Science*, 2001.
- Gilbert, J. K. (1985); Swift, D.J. - Towards a lakatosian analysis of the piagetian and alternative conceptions research programs. *Science Education* Volume 69, Issue 5, pages 681–696, October 1985.
- Glencoe Science. (2005) Physics, Principles and Problems. *The CMGraw-Hill Companies, Inc.* (2005).
- Hampson, P.J. and Morris, P.E. (1996). Understanding cognition. Cambridge, MA: Blackwell Publishers Inc.
- Ingham, A. (1991). 'The Use of Analogue Models by Students of Chemistry at Higher Education Level', *International Journal of Science Education* **13**(2), 193–202.
- Izquierdo-Aymerich, M. (2005). Hacia Una Teoría De Los Contenidos Escolares. *Enseñanza de las ciencias*. Available in: <http://ddd.uab.cat/pub/edlc/02124521v23n1/02124521v23n1p111.pdf>. Accessed on 12/11/2014
- Izquierdo-Aymerich, M. & Adúriz-Bravo, A. (2003) - Epistemological foundations of school science. - *Science & Education*, Kluwer Academic Publishers. Printed in the Netherlands. Pg. 23.
- Izquierdo-Aymerich, M., Sanmartí, N. & Spinet, M. (1999) Fundamentación Y Diseño De Las Prácticas Escolares De Ciencias Experimentales. *Enseñanza De Las Ciencias*, 17 (1), 45-59.
- Johnson-Laird, P. N. (1995). Mental Models. 6th Edition. Printed in USA. *Cognitive Science Series*.
- Johnson-Laird, P. N. (1987). Modelos mentales en ciencia cognitiva. NORMAN, D. A. *Perspectivas de la ciencia cognitiva*. Barcelona: Ediciones Paidós, p. 179 - 231.

Kuhn, T. (1998). The Structure of Scientific Revolution. Chicago. *The University of Chicago*. (1970). A Estrutura das Revoluções Científicas. *Coleção Debates*. Ed. Perspectiva.

Latour, Bruno. (1999) Pandora's hope: essays on the reality of science studies. *Harvard University Press*, 1999.

author, L. A. (2016a). Concept Maps as a Tool for Evaluation of Modern Physics Contents in Textbooks. *Investigações em Ensino de Ciências*. To be publish.

author, L. A. (2016b). The use of Concepts Mapping in the Science Paradigm Transposition and the Cognitive Science Theory – The Case of Black Body Radiation. *Investigações em Ensino de Ciências*. To be publish.

author, L. A. (2016c) - The Use of Concept Maps in the Evaluation of Cognitive Models of Science. The Photoelectric Effect. *Investigações em Ensino de Ciências*. To be publish.

Moreira, M. A. (1996), Modelos Mentais. *Investigações em Ensino de Ciências* – V1(3), pp.193-232.

Moreira, M. A., I. M. Greca, and M. L. R. Palmero (2002) - Modelos Mentales Y Modelos Conceptuales. *En La Enseñanza & Aprendizaje de Las Ciencias* 13 (Mental models and conceptual models in the teaching & learning of science). *Revista Brasileira de Investigação em Educação em Ciências* 2.3 (2002): 84-96.

Nersessian, N.J. How do Scientist Think? (1992). Capturing the dynamics of Conceptual Change in Science. *Cognitive models of science*, pg.3.

Novak, J. D. & Cañas, A.J. (2006). The Theory Underlying Concept Maps and How to Construct Them. *Technical Report IHCM CmapTools 2006-01*. Available in: http://www.vcu.edu/cte/workshops/teaching_learning/2008_resources/TheoryUnderlyingConceptMaps.pdf. Accessed on 01/05/2014

Schnotz, Wolfgang. (2005) "An integrated model of text and picture comprehension." *The Cambridge handbook of multimedia learning* (2005): 49-69.